

The Hualin Papermaking Mill Remains in Gao'an City, Jiangxi

Jiangxi Provincial Institute of Cultural Relics
and Archaeology and Gao'an Municipal Museum

Abstract

The excavations to the Papermaking Mill Remains at Fuzhimiao Workshop Zone in Hualin District recovered architectural remains related to papermaking; at Zhouling and Xixi Villages, seven water-powered trip hammers were recovered respectively. These recovered papermaking facilities reflected the entire workflow from falling bamboo (as raw material of paper), material retting, material boiling, material fermenting and material pulverizing to filling and paper conditioning and could be used to restore the occasion of “Making Bamboo Paper” in *Tiangong Kaiwu* (Exploitation of the Work of Nature) written by Song Yingxing.

Keywords: Hualin Papermaking Mill Remains (Gao'an City, Jiangxi); papermaking—history—Song to Ming Dynasties; workshop sites.

Introduction

The Hualin Papermaking Mill Remains are an assemblage of localities of industrial remains pertained to papermaking of the past. They are distributed in the vicinity of Zhouling Village of Dongxi Administrative Village, Hualin Scenic Regulatory Commission, Gao'an City. The village situates on the waist of a hill and wrapped by mountains on four sides.

The Hualin Papermaking Mill Sites were discovered in 2005 when the staff of Gao'an Municipal Museum encountered the remains of 16 localities of water-powered trip hammer sets at Zhouling Village during the third provincial census of cultural heritage of Jiangxi. Since then, the Jiangxi Provincial Institute of Cultural Relics and Archaeology and the Gao'an Municipal Museum had joined force for two seasons of archaeological field campaign on the sites from September to October, 2007, and from October to December, 2009.

The archaeological campaign

on Hualin Papermaking Mill Remains comprised of four components. (1) Excavations at the sites of seven water-powered trip hammer sets in Zhouling Village. (2) Excavations at the sites of seven water-powered trip hammer sets in Xixi Village. (3) Survey the locations of soaking pools in the mountains behind Zhouling Village and the sites of sheet-forming facilities around the village and (4) Excavations at the Fuzhimiao workshop site.

Water-powered trip hammer sets in Zhouling Village

Despite the straight line distance between Zhouling and Fuzhimiao is less than 500m, remains of seven water-powered trip hammer sets are densely distributed along the Shinaotou Brook (Figure 1). According to the variation of beating benches, they can be classified into three types.

Type I water-powered trip hammer set comprises of one example (Trip Hammer 2). The facility had two stone mortars placed on the working space and a stone slab was set in front of the mortars. No beating mark was seen on the stone slab. Evidently, the stone slab was only functioned as a weight to stabilize the mortar rather than as an anvil. Moreover, it was the only trip hammer that yielded a wall foundation (Figures 2 and 3). According to local informants, villagers had been using this trip hammer to pound rice before the introduction of machine milling in the 1980s. Among the seven water-powered trip hammer sets of Zhouling, Trip Hammer 2 was the last one

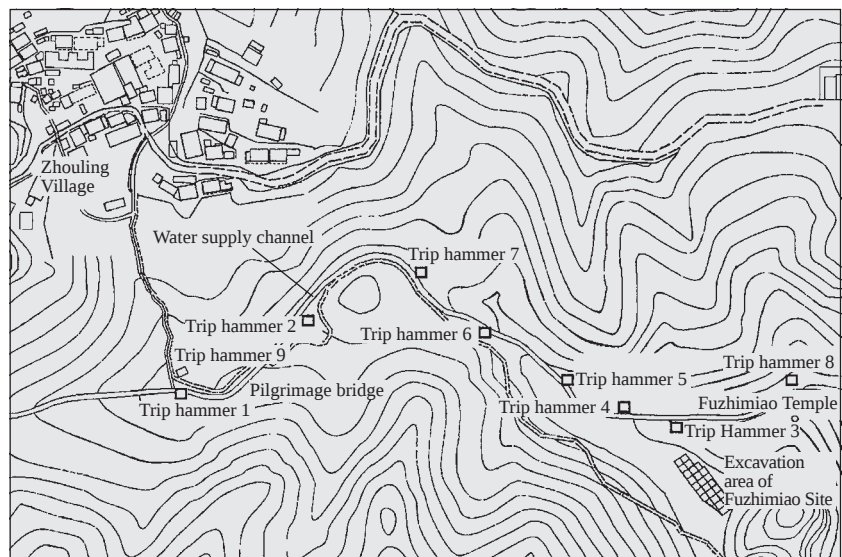


Figure 1 The distribution of water-powered trip hammer sets in Zhouling Village.

to be decommissioned. It is evident that this hammer was used as a food processing device.

Type II water-powered trip hammer comprises of two examples (Trip Hammers 1 and 3). A shared feature of the facilities of this type is that two stone slabs and one stone mortar were placed on the working space of the trip hammer (Figure 4). For instance, two stone slabs were placed perpendicular to one another in Trip Hammer 3. Both showed concave surfaces attributable to repeated pounding, indicating that the slabs had been used as anvils (Figures 5 and 6). The stone mortar also showed pounding marks. Moreover, a worn-out mortar with perforated base was found beside it.

Type III water-powered trip hammer comprises of four examples (Trip Hammers 4 through 7). They are distributed on the banks of the brook, in between Trip Hammers 2 and 3. They had two stone anvils in the working space, but no stone mortar was found (Figure 7). This arrangement suggests that they had never been used for food processing. Instead they were solely used for the processing of papermaking materials like bamboo and hemp.

The service dates of these seven water-powered trip hammer sets vary. Trip Hammers 2 is the only trip hammer that showed remains of a masonry wall foundation. The working spaces of trip hammers 1 and 3 showed remains of stone encircles. Trip Hammers 4, 5, 6, and 7 sustained heavy disturbance that no remains of masonry encircle was found. Even the stone beams that used for the setting of axle on the walls of the waterwheel pool were missing from these trip hammers. Type I water-powered trip hammer sets had the highest degree of preservation; wherein type III facilities had the lowest degree. These structures were exposed in the open air and subjected to erosion and continuous disturbance. Some wood remains from collapsed beams and posts were recovered from them. They need to be tested to determine the absolute dates of the trip hammers. A few sherds of blue-and-white ware of Jingdezhen folk kiln and local Longquan celadon were yielded from the lower

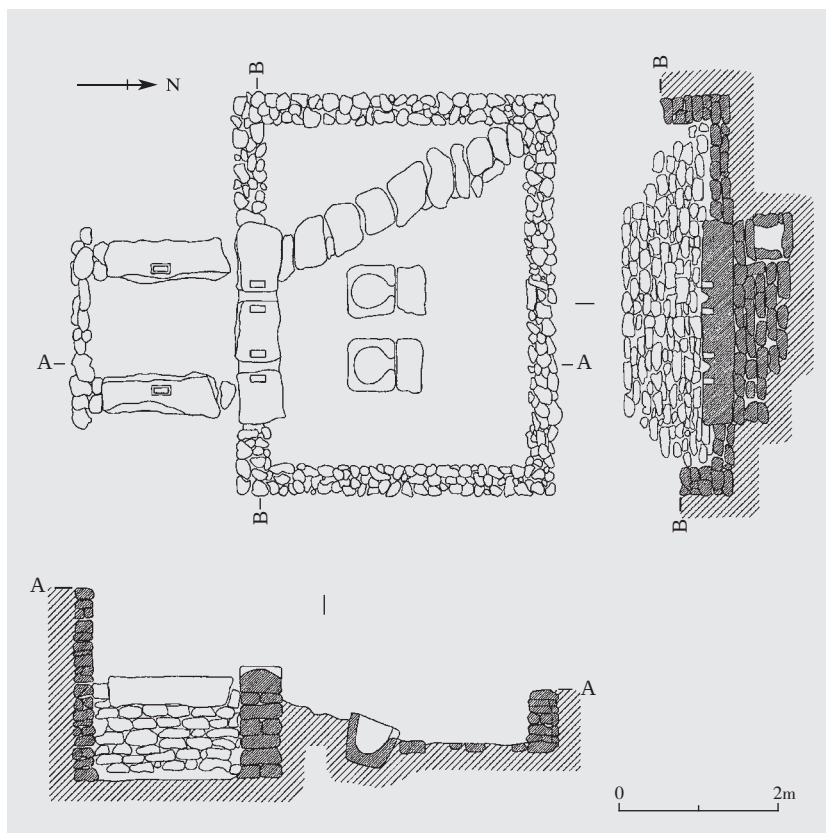


Figure 2 The plan and section of trip hammer 2 at Zhouling Village.



Figure 3 Trip hammer 2 at Zhouling Village (N-S).

deposition of the waterwheel pool of Trip Hammers 1 and 3, suggesting that type II trip hammers might have been decommissioned between the mid to late Ming Dynasty.

During the 2009 field season, a 2m square test pit was dug in the southern edge of the working space of Trip



Figure 4 Trip hammer 1 at Zhouling Village (NW–SE).

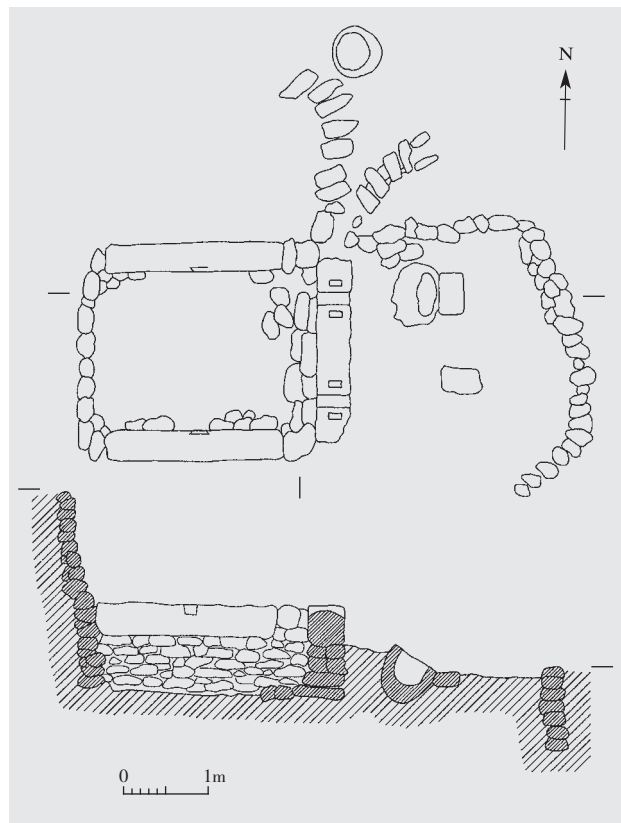


Figure 5 The plan and section of trip hammer 3 at Zhouling Village.



Figure 6 Trip hammer 3 at Zhouling Village (E–W).

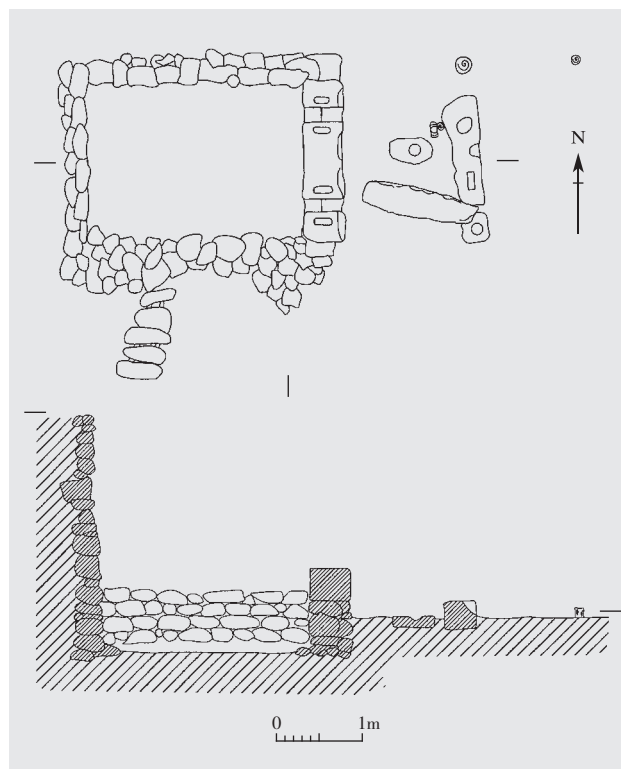


Figure 7 The plan and section of trip hammer 4 at Zhouling Village.

Hammers 3. On the one hand, the rock base of the unit yielded a few sherds of glaze-rimmed engraved bluish-white ware diagnostic to Southern Song, and a bronze coin known as “Chongning Double Coin” 崇宁重宝 dated to Song Emperor Huizong (宋徽宗). On the other hand, the upper layers of the same test unit yielded sherds of bluish-white ware with unglazed rims of the Yuan times, and blue and white ware of Jingdezhen folk kiln and local Longquan celadon of the Ming times. These chronological characteristics are consistent with those revealed in the deposition of the neighboring Fuzhimiao workshop site. Based on these several lines of evidences, we argue that Trip Hammer 3 was erected during the times of Southern Song, and continued to be in service for the next five centuries through the Yuan and Ming eras.

Water-powered trip hammer sets in Xixi Village

In 2009, archaeologists surveyed and excavated seven water-powered trip hammer sets in the vicinity of Xixi Village, about 10km from Dongling Village, in the Huanlin Township. Only one of the seven trip hammers, the one located on the edge of the village, was type I trip hammer equipped with two stone mortars. The remaining trip hammers were type III equipped with two stone anvils. No type II trip hammer was found (Figure 8).

The discovery of 14 water-powered trip hammer sets in two villages told the same story. A village needed no more than one water-powered trip hammer to meet all the domestic needs of food-processing of all households. The remaining ones were water-powered trip hammers equipped with stone anvils for the papermaking industry.

The existence of type II water-powered trip hammer sets indicates that these facilities had dual functions of food processing and pulp beating. Alternatively, written documents suggest that the production of high grade paper entailed two rounds of pulp beating. The first round of rough beating would have been performed on the beating anvil. The second round of fine beating would have been done in the mortar.

The discovery of three types of water-powered trip hammer sets first indicates that there are papermaking workshop sites in Hualin. Second, it provides new material for the study of the evolution of water-powered trip hammer sets pertaining to the traditional craft of papermaking. Third, it provides a reference point for the search of ancient papermaking sites in other parts of the world.

Reconnaissance of soaking pools and sheet-forming workshop sites

According to local informants, in addition to the remains of water-powered trip hammer sets, features related to the papermaking industry also included soaking pools distributed among bamboo groves. These pools were used for the soaking of bamboo after they were cut. As workers cut down the new tender bamboos, they would have submerged them into the pools to soften the material. We discovered more than twenty soaking pools in the mountains at the back of Zhouling Village. Most of them had been damaged to certain extent. Today, better preserved soaking pools can only be found among the bamboo groves in higher elevation.

Sheet-forming workshop is locally known as *caofang* 槽房. They were the facilities where fiber slurry was transformed into sheets of paper. In *Tiangong Kaiwu* 天工开物 (Exploitation of the Works of Nature), Song Yingxing 宋应星 presented two illustrations of the processes of molding and pressing in the craft of sheet forming. Both processes were completed in sheet-forming workshops. Villagers said that there were four sheet-forming workshops in Zhouling Village around the year of Liberation. Their localities are now occupied by residential structures and sheds.

Excavations at Fuzhimiao Papermaking Mill Site

Fuzhimiao Papermaking Mill Site is located in a glen about 500m southeast of Zhouling Village. It was named

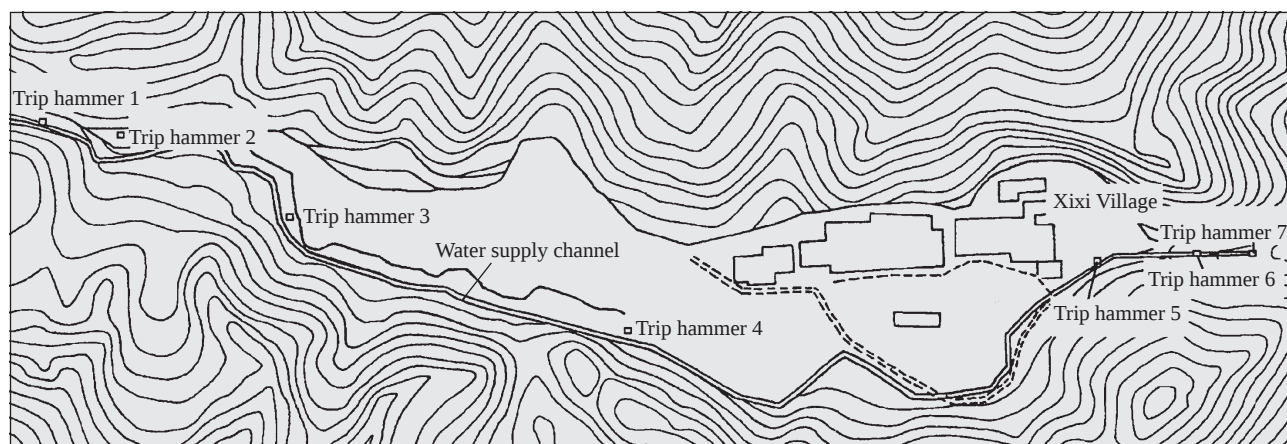


Figure 8 The distribution of water-powered trip hammer sets in Xixi Village.

after a temple called Fuzhimiao that stands above the glen. The glen has since been developed into terraces. The winding path leading from the village down the hill passes through the top terraces. Shinaotou Brook runs below the terraces.

In 2007, ten 5 x 5m grids were placed and excavated on the site. In 2009, sixteen 5 x 5m grids on the periphery were excavated. Areas in total of 650sq m were excavated during the two terms of operation (Figure 9).

1. Stratigraphy. The eastern part of the excavation area yielded the thickest deposition. For instance, the east wall of unit T0204 showed 1.55m of cultural deposition. Their color and texture suggested that they were divided into six layers. Layer 1 was the cultivated soil. Layer 2 was the Ming fillings. Layer 3 was the deposits of mid to late Ming. Layer 4 was dated to mid through late Yuan. Layer 5 did not yield any cultural remains. Finally, level 6 was dated to late Tang through Five Dynasties, and no later

than early Northern Song (Figure 10).

2. Features. Four occupation floors were found (Figure 11).

A late Ming to early Qing occupation floor was located underneath Layer 1. Remains of a set of Ming structures outcropped at the base of Layer 1. They comprised mainly of masonry wall foundations and post footings. These features cut into Layer 2 and sat above Layer 3. The latest artifacts yielded from Layer 3 were sherds of blue-and-white wares dated around the Zhengde 正德 Era of mid Ming. Therefore, the earliest construction date of this structure would be mid to late Ming.

Features attributable to the papermaking industry of late Yuan and early Ming were found at the base of Layer 3. A set of papermaking features outcropped at the base of Layer 3 were the best preserved and the most numerous in the site. They were dated to the terminal years of Yuan and prior to mid Ming. This set of features included

soaking pools (F1 and H8), a large reddish baked clay surface pertained to the boiling process (F2), a workbench for ash mixing and fermentation (F3, see Figure 17), remains of a lime heap (F4), a lime pit (H2), a residue pit (H6), traces of water supply line (G3), and some remains of retaining wall.

Features attributable to papermaking of the Yuan era were found in the base of Layer 4B. They included a half moon shape stone lined soaking pool (H3), seven postholes (Z1, Z2, Z3, Z4, Z5, Z7, Z6), five ash pits (H5, H9, H10, H11, H12), a slice of reddish baked clay surface (F6), and a section of pottery



Figure 9 Full-view of the excavation area of Fuzhimiao Site (N-S).

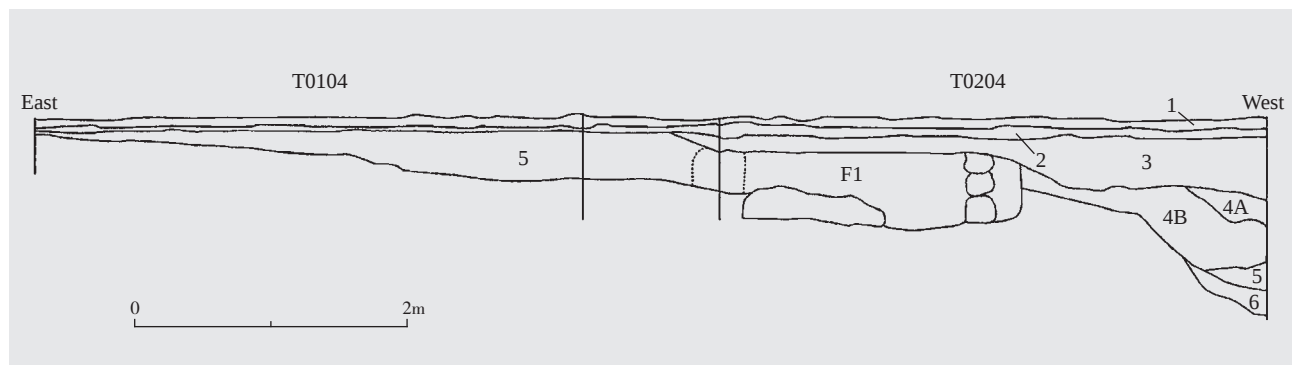


Figure 10 The section of the south wall of T0104 and T0204.

1. gray soil 2. loess 3. dark gray soil 4A. yellowish-brown hard-packed earth 4B. grayish-brown soil 5. light yellow hard-packed earth 6. grayish-brown clay

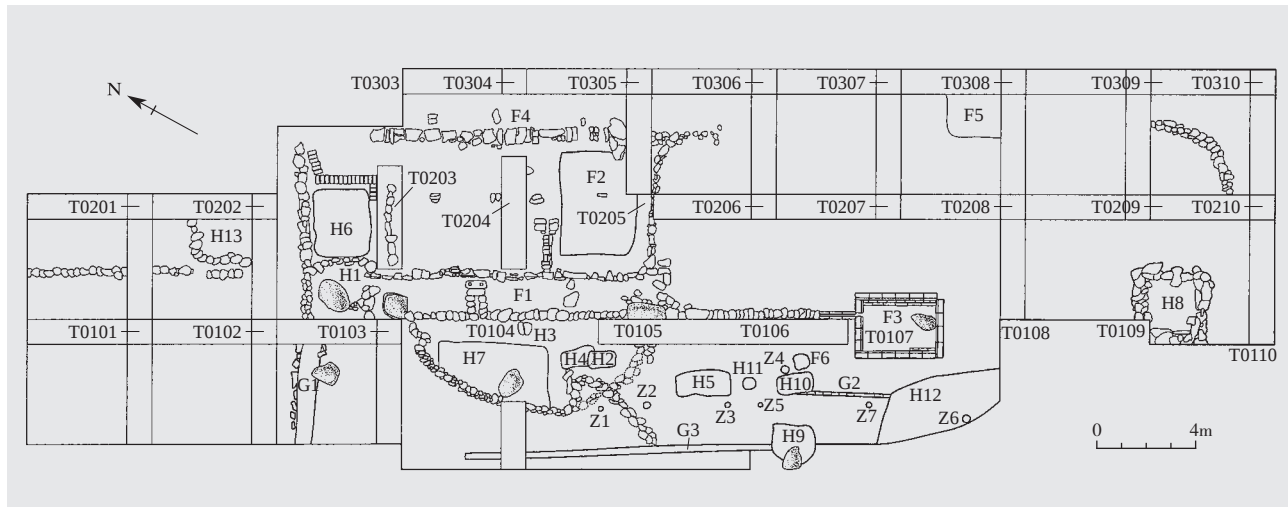


Figure 11 The distribution of the features in the excavation area of Fuzhimiao Site.

pipe (G2). The artifact assemblage comprised of small amount of bluish white porcelain sherds with unglazed rims diagnosed to the Yuan Dynasty. Blue-and-white ware of the Ming was completely absent. Therefore, this set of structures was built no later than the Yuan Dynasty, and they were also abandoned during the Yuan.

The Song features outcropped at the base of Layer 5. Excavation of the Song features was constrained by the intention of preserving the Yuan and Ming features of the upper layers. As a result, limited number of Song features was yielded during the excavation. Only two rectangular pits dated to the Song Dynasty were yielded from T0104.

3. Interpretation of the archaeological features. Past literatures depicting the traditional craft of papermaking provide historical analogies to interpret the various features found at Fuzhimiao mill site. The features included mainly of the remains of soaking pool, an extensive reddish baked clay surface resulted from steaming and cooking, a workbench for ash mixing and fermenting, ash pits used for lime processing, remains of lime heap, a residue pit from pool cleaning, traces of water supply line and drainage, and remains of the sheet-forming process that included hearth base for additive cooking, water barrels, foundation of the workshop structure and postholes. Together with the findings at Trip Hammer 3 located near the Fuzhimiao Site, we can reconstruct a complete workflow in a past papermaking industry that included bamboo cutting, soaking, cooking, fermenting, beating, pulping, and sheet-forming.

Soaking pool. The pool was used for the soaking of bamboo and other papermaking materials. After extended soaking, cellulose of young bamboo stem would separate like hemp bark and be fine as silk. They are generally called bamboo hemp or bamboo silk in southern China. Several historical documents delineated the use of soaking pools in the paper industry. For instance, Song Yingxing wrote in the “Debarking” chapter of *Tiangong Kaiwu* volume II, “During the season of Mangzhong,

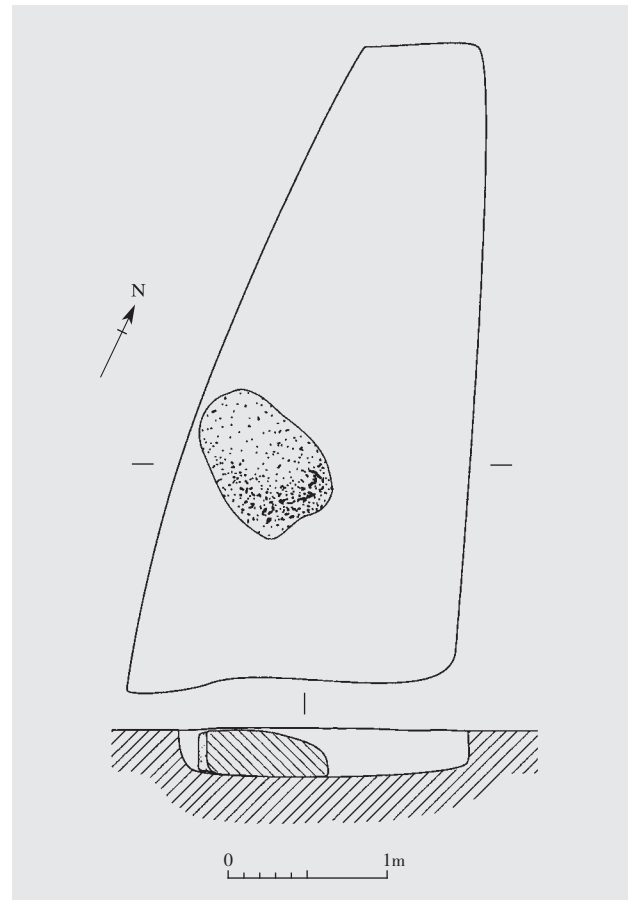


Figure 12 The plan and section of soaking pool H7.

the bamboos on the mountains with new branches about to come out are cut into pieces from five to seven feet long. A pool is dug right there in the mountain and filled with water in which the bamboo stems are soaked...After soaking for more than one hundred days, the bamboos are carefully pounded and washed to remove the coarse husk

and green bark. This process is called debarking (English translation by Sun and Sun).” Song further illustrated the process with a diagram entitled “Steeping and Washing Cut Bamboo.” In Jiangxi, this kind of soaking facilities is called *ou zhuma tang* 沤竹麻塘 or *hutang* 湖塘.

The excavations at Fuzhimiao workshop site revealed three different types of soaking pools. They were the rectangular pit of the Song Dynasty (H7, see Figure 12), the half-moon stone lined pool of the Yuan Dynasty (H3, see Figure 13), and finally the rectangular stone lined pool of the Ming Dynasty (F1 and H8, see Figures 14 and 15). This sequence of development reflects the evolution of the design of soaking pools. Each of these pools had a stone workbench in the center, which was equipped to facilitate the beating of bamboo material. Pools H3 and H7 shared a large tortoiseshell shaped workbench (Figure 11). The Ming pool F1 showed improvement from the previous pools in many ways. First, the pool was divided into an upper pond and a lower pond separated by a wall but connected by a conduit. Second, a whetstone for tool sharpening was located at the outlet drain of the lower pond. Third, a brick-lined drainage situated about 40cm higher than the base of the upper pond. It was likely used to regulate the water level of the pool. Fourth, there was a

channel connecting the pool and the workbench F3 to its south (Figure 11). These several areas indicated F1 made improvements in the design of soaking pool.

Stratigraphy of the soaking pools of different eras. Feature H3 was superimposed over feature H7. Pool H3 was modified and expanded on the previous Southern Song pool H7. It intruded into the western half of H7. Incidentally, the eastern part of H3 was intruded into by the Ming pool F1. Its southern edge was intruded into by H2. The remaining north wall of the pool intersected with the west wall of F1. Our observations indicated that H3 was intruded into by F1 in this area (Figure 11).

An extensive surface of reddish baked clay related to the steaming and boiling of raw material (F2). Again, we quote Song Yingxing, who wrote in the bamboo paper making section of *Tiangong Kaiwu*, “The pot for boiling bamboo, four feet in diameter, is enclosed in a wooden cask, measuring fifteen feet in circumference and more than four feet in diameter. The pot is attached to the cask with the aid of mud and lime and has a capacity of some ten *dan* (30 bushels or so) of water. The cask is covered for boiling for eight days. After the fire has been put out for one day, the bamboo fibers are taken from the cask and thoroughly washed in a pool with clean water (Sun

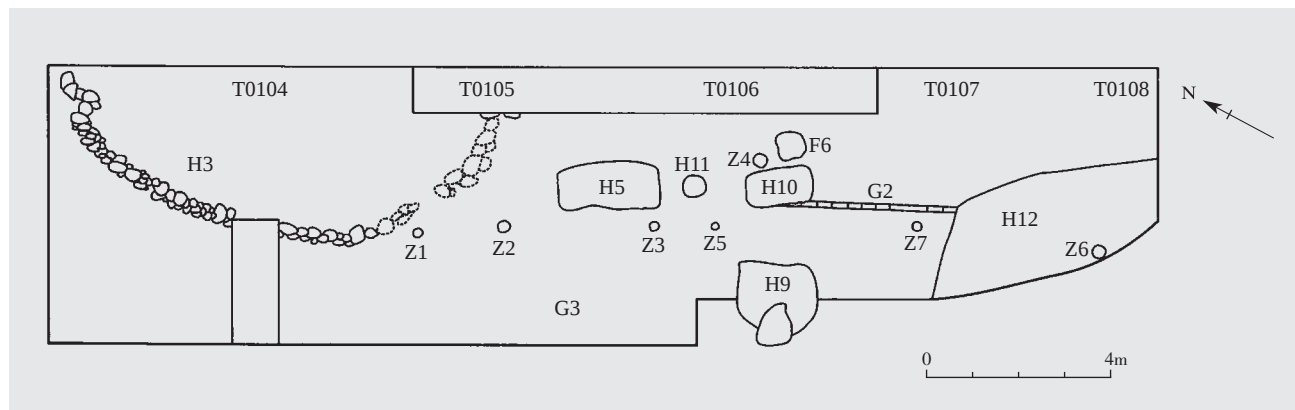


Figure 13 The distribution of the features of the Yuan Dynasty.

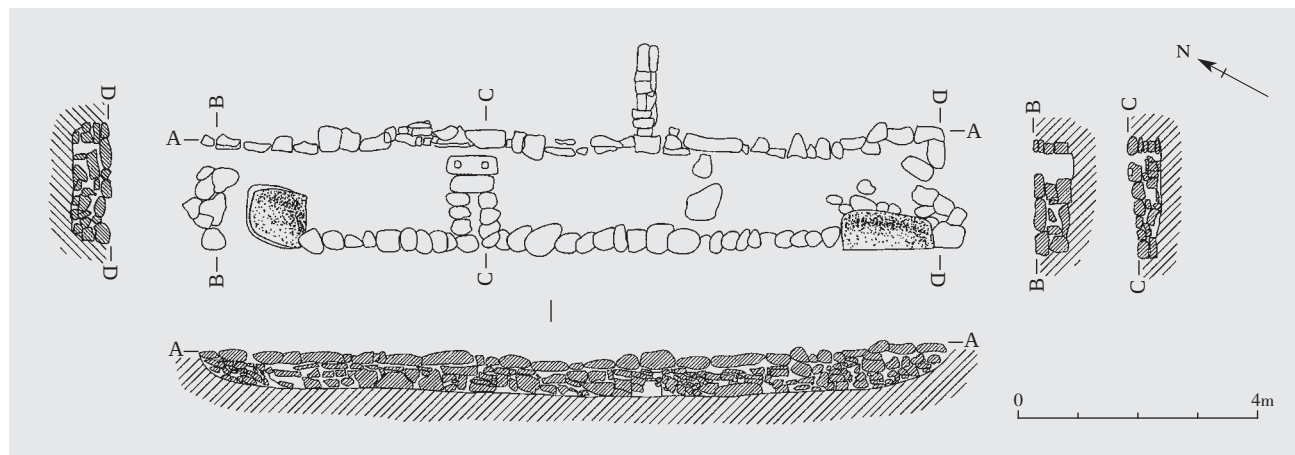


Figure 14 The plan and sections of soaking pool F1.

and Sun's translation)." He illustrated the process with a diagram titled "Cooking the Inner Mass of Bamboo in a Pot". The excavation revealed an extensive surface of reddish baked clay (F2) located to the southeast of structure F1. It measured 3.1m from north to south, 2.4m from east to west and 20cm thick, making a surface of 7.44sq m. It showed charcoal color or reddish brown color resulted from long time baking. This feature of reddish baked clay was unusually extensive. It was very likely the remains of a large hearth for cooking of bamboo material (Figure 16).

A workbench for ash mixing and fermentation (F3). The rectangular feature measured 3.4m long and 4.1m wide. The floor was lined with blue bricks and encircled with stretcher stone slabs of 0.7m long and 0.15m wide. A gap was left out between the encircling slabs and the lining bricks, forming a ditch of about 0.2m wide and 0.05m deep. The ditch's outlet was located in the northeastern corner and was connected to a north-south running brick-lined covered drainage which in turn emptied into the soaking pool F1 of the Ming time. A large stone was placed on the southern end of the working surface, which was probably used for the beating and pounding of the bamboo material. This feature, therefore, should be interpreted as a workbench for ash mixing and fermentation (Figures 17 and 18).

Pits for ash alkalis. Many past literatures concerning papermaking mentioned that alkalis made of plant ash were used as catalyst to accelerate the pulping process. Three rectangular ash pits were revealed by the 2009 excavation. They included H2 (Figure 19) of the Ming Dynasty, H5 of the Yuan Dynasty, and H4 of the Song Dynasty. Considerable quantities of charcoal ashes were recovered from these pits. Furthermore, all three pits neighbored with their contemporary soaking ponds. Because of that, we determine that they were pits for the preparation of ash alkalis.

Remains of lime heap. The bamboo paper making chapter of *Tiangong Kaiwu* described, "The inner fibers of the bamboo, with a hemp-like appearance, are mixed with high-grade lime in a thick fluid and put into a pot to be boiled over a fire for eight days and nights (Sun and Sun's translation)." Lime was used in pulp cooking in traditional papermaking industry. Its location should be in proximity of the cooking area. An extensive deposition of mixed sediment (F4) attributable to the piling of lime was found in the Ming occupation of Fuzhimiao. It was located in the center of the grid square immediate south of the cooking area F2. Among the deposition, a layer of rectangular mixed sediment was quite distinctive (Figure 11).

Water supply line of early Ming (G3). Traces left by a water supply line were seen in the higher elevation of the western portion of the excavation area. G3 was a water channel of about 10m long, 20cm wide and 8cm deep (Figure 11).



Figure 15 Soaking pool F1 (N-S)

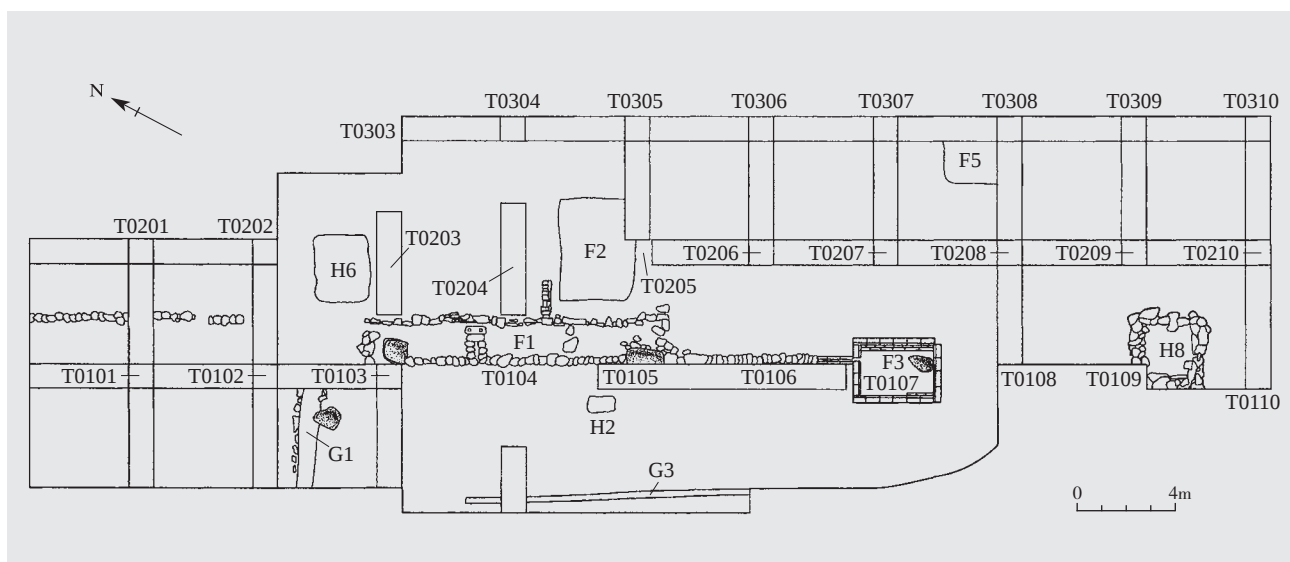


Figure 16 The distribution of the features of the early Ming Dynasty.

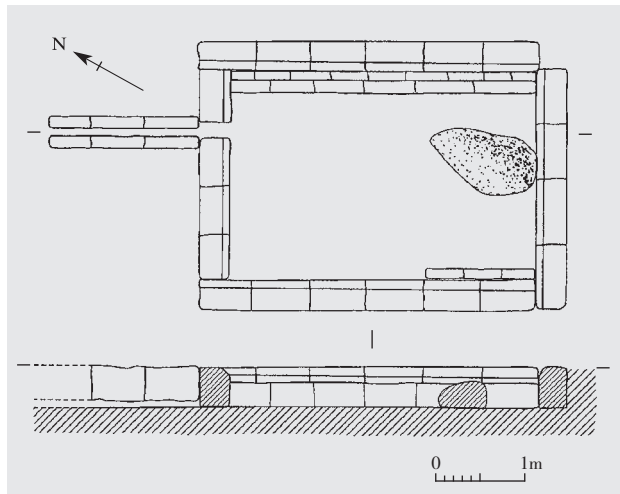


Figure 17 The plan and section of F3.



Figure 18 F3 (S-N).

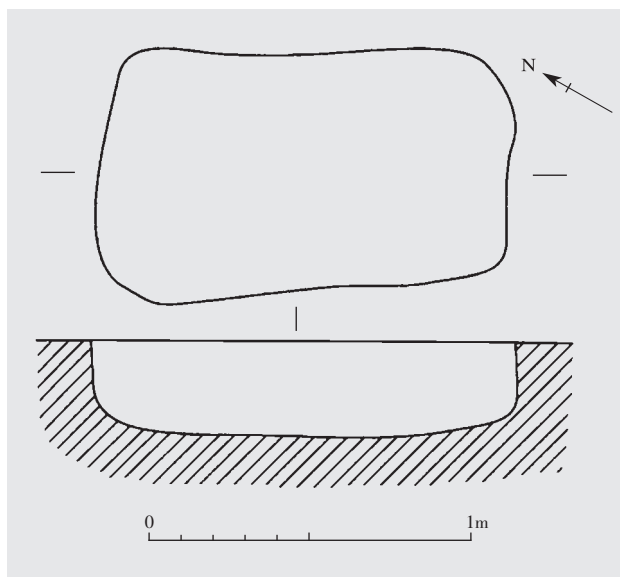


Figure 19 The plan and section of H2.

Residue pit from pool cleaning (H6). Workers of a paper workshop needed to periodically clean up the sediments of the soaking pool. Located next to the outlet of F1, H6 was an early Ming pit dug for the disposal of the sediments from pool cleaning. Its deposition comprised of pure, fine, damp, and soft sandy silt. They were sediments from hydraulic sorting. The deposit was thinner on the west side and thicker on the east side. The deposit on the east wall of T0203 was 0.6m thick (Figure 11).

Sheet-forming facility of the Yuan Dynasty. The archaeological campaign revealed an assemblage of Yuan features that entailed a sheet-forming facility (Figure 13). They included three ash pits (H10, H11 and H5), six postholes (Z1–Z5 and Z7), hearth (F6), pottery pipe (G2), water pit (H12). The structure was a shack shored by lumber posts. Features H5 and H10 were two flat-bottomed rectangular pits used to stabilize two dipper-shaped wood troughs. Feature H5 was longer than its counterpart. It was likely used for sheet molding. Feature H10 was the receptacle for pulp slurry. The round pit (H11) located in between these two features was where the pottery vat for additives of the slurry sat. The hearth-shaped reddish baked clay surface (F6) on its side was the remains of the stove for additive cooking. Waste water was drained into the drainage (G2), flowed east, and eventually emptied into the collecting pit (H12) in the south.

Workflow indicated by the remains of Ming papermaking activities. Remains pertained to the papermaking industry of the Ming Dynasty revealed by the excavations at Fuzhimiao were the largest in number and the most comprehensive. Together, they wove a picture of the workflow of an ancient craft that turned bamboo stems into sheets of paper. To start, the workers disposed the bamboo stems into the soaking pool (F1). After extended soaking, they retrieved the bamboo, beat them on the stone workbench located on the northern end of the pool, and removed the green bark from the stems (debarking). They then washed and cleaned them in the upper pool. The cleaned material was steamed and boiled with lime in the neighboring cooking area (F2). The cooked material was recovered from the pot and went through a second round of washing and cleaning in the pool. They were transported to the ash mixing and fermentation area (F3) for seasoning. Ash alkalis were fetched from the ash pit (H2) to mix with the cooked material. In case the workers found bamboo stems that had not been fully processed, they would beat them on the anvil of the workbench. After mixing, they returned the material to F2 for a new round of boiling, washing in the pool, and back to the workbench (F3) for fermentation and sunlight bleaching. The excessive alkaline solution from fermenting would have flowed into the soaking pond (F1) through the drainage located in the northwestern corner of the workbench. It would become the catalyst in cellulose extraction. Therefore, F1 was in fact a lime pool. The fully fermented and bleached material would then be transported to the nearby Trip Hammer 3 for final beating to complete the pulping process.

Major archaeological findings

1. The excavations at Hualin Papermaking Mill Sites of the Song, Yuan and Ming Dynasties are unprecedented in Chinese archaeology. The findings are extremely significant in the study of the technological development of papermaking in ancient China.

2. Hualin Papermaking Mill Sites of the Song, Yuan and Ming Dynasties yielded the highest number of archaeological features of the past papermaking industry. The two terms of archaeological campaign revealed 42 localities attributable to papermaking activities.

3. Hualin Papermaking Mill Sites revealed the most complete set of features in papermaking industry in China. These features reflected the processes of bamboo cutting, soaking, steaming and cooking, fermenting, beating, pulping, and sheet-forming. These findings support the reconstruction of the workflow in the making of bamboo paper of the past.

4. Hualin Papermaking Mill Sites are the earliest (Southern Song) and the longest (Southern Song, Yuan and Ming) papermaking industry sites ever discovered

in China. They showed clear stratigraphic relationship. The excavations at Hualin Papermaking Mill Sites of the Song, Yuan and Ming eras won the honors of “The 2009 Top Archaeological Discoveries” of the Archaeology Forum of the Chinese Academy of Social Sciences, and “The 2009 Top Ten Discoveries in Archaeology” of the State Administration of Cultural Heritage.

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Postscript

The original report published in *Koagu* 考古 2010. 8: 53–71 with 32 illustrations and two plates was written by Wang Yile 王意乐, Liu Jincheng 刘金成 and Xiao Fabiao 肖发标. The summary was prepared by Xiao Fabiao and translated into English by Lee Yun Kuen 李润权.